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GB 2316965 A US 5350015 A US 5018580 A

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EPODOC,WPI,JAPIO

(54) Abstract Title
Reusable cutting and milling tool

(57) A tool for milling or cutting tubular members downhole in a well, has pivotable blades 14 pivoted upwardly by upward movement of a hollow cylindrical hydraulic piston 20 within the tool body 12. The piston wall is directly below and aligned with the blade, minimizing the diameter of the tool. A fluid tell-tale is provided to indicate the extent of deployment of the blades. The blades can be withdrawn by driving the piston downwardly. In operation, fluid passes along passageway 22 and enters space 26 below the piston via ports 33. When the piston is forced upwardly the movement of pin 36 in slot 38 forces the blades outwardly. When plug 32 clears port 32, the fluid pressure will drop which indicates to an operator that the blades have been deployed. To close the blades a ball 25 is used to close the fluid passageway. Fluid pressure is then used to move the piston downwardly. The pin and slot arrangement give a positive movement of the blades inwardly. In an alternative embodiment the piston has a pin that operates each blade.

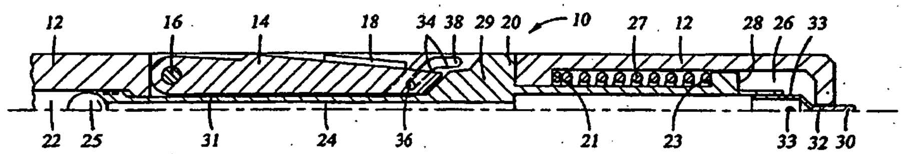

Fig. 1

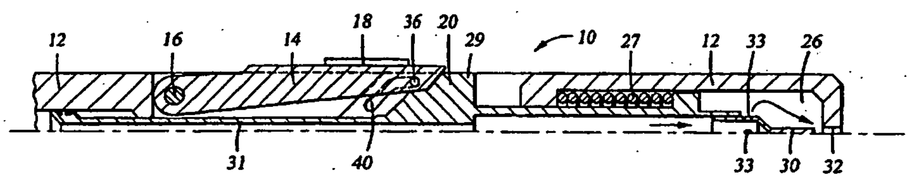

Fig. 2

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

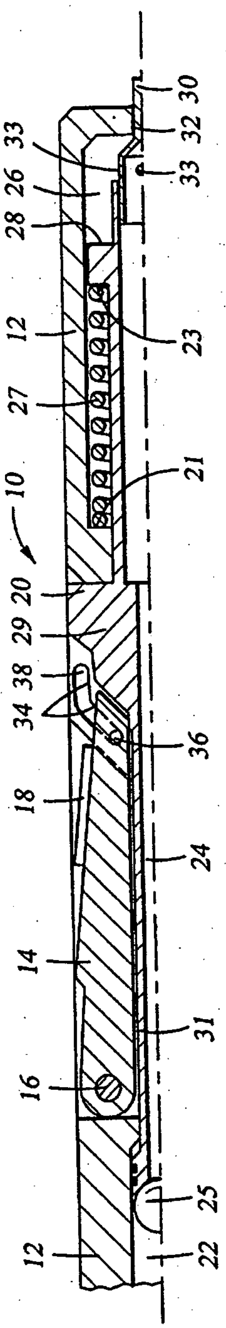
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Fig. 1

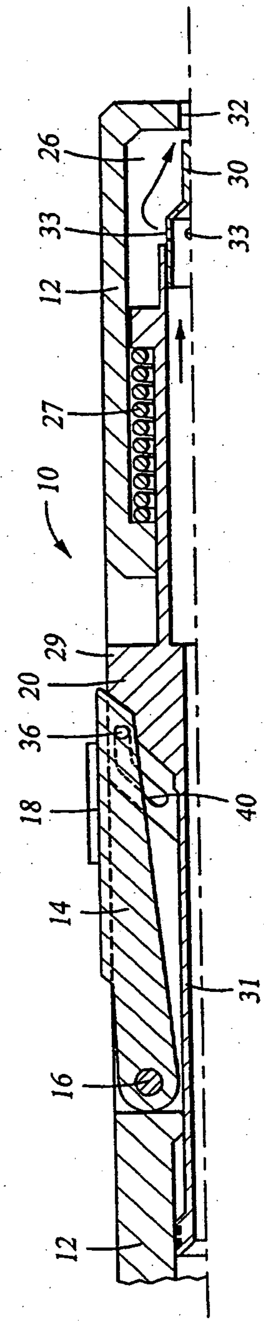
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Fig. 2

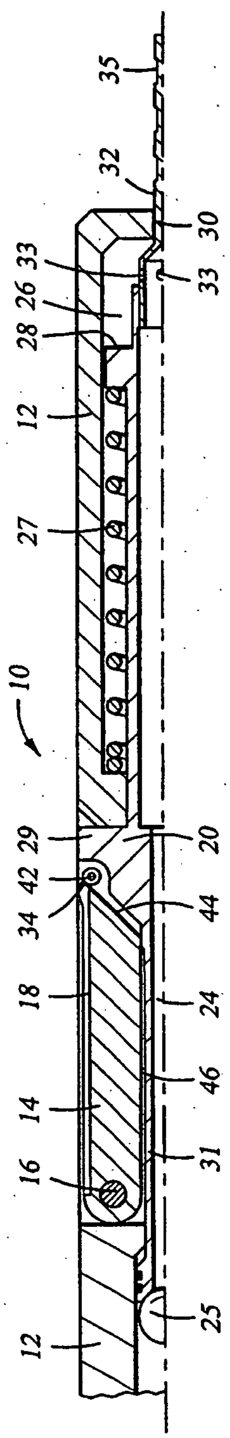
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Fig. 3

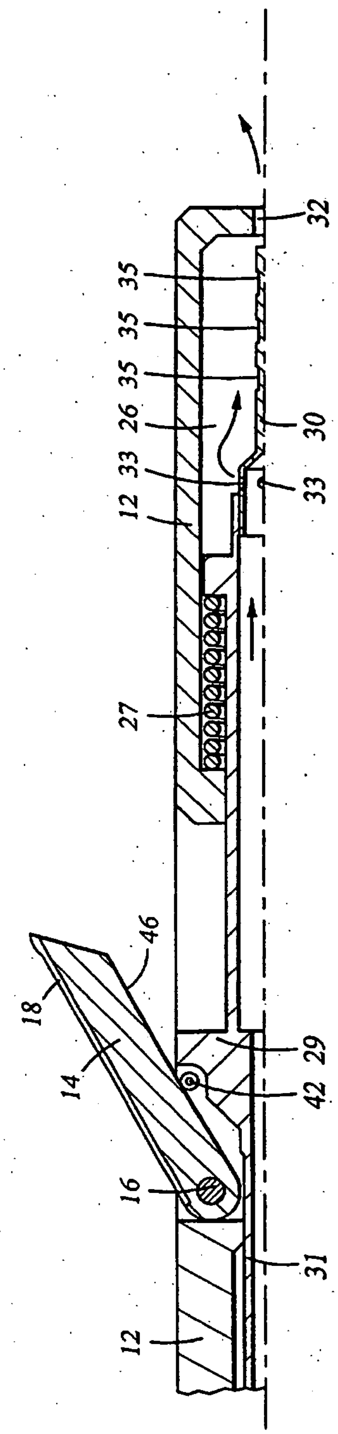
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Fig. 4

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TITLE OF THE INVENTION

Reusable Cutting and Milling Tool

BACKGROUND OF THE INVENTION

Field of the Invention - This invention is in the field of tools used downhole in an oil or gas well, to mill out tubular elements, such as pipe or casing, to cut through and release a section of casing, or to underream a formation.

Background Information - In drilling or reworking an oil or gas well, it often becomes necessary to perform a variety of downhole cutting or milling operations. Many of these cutting or milling operations are performed on tubular elements stuck downhole, such as production tubing, piping, or casing. Other such operations may be performed on the borehole itself, such as when a borehole is underreamed to open up the diameter of the borehole below a selected depth.

In these cutting or milling operations, it is typical to have a tool with a plurality of blades or knives which deploy outwardly to come into cutting contact with the stuck tubular element or the borehole wall. Such tools often are limited in their ability to forcefully deploy the blades, since the tool itself must be of small enough diameter to fit down the bore hole, and often into the tubular element itself.

Various mechanisms have been devised to deploy the cutting blades. Most often, it is desirable to have the cutting blade pivoted about a pin near the upper end of the blade, to allow the storage of the blades in slots in the tool body until the tool is positioned where the cutting or milling is to take place. At that point, the blades are typically pivoted outwardly and upwardly to come into contact with the surface which is to be cut or milled. Pivoting of the blades is often accomplished by hydraulically driving a piston downwardly, which exerts a downward force on the upper ends of the pivotable blades.

Since the blade is pivoted about a point near its upper end, the upper moment arm from the point of contact with the piston to the pivot point is very short, compared to the length of the blade below the pivot point. This severely limits the force with which the cutting edge of the blade can be forced against the tubular element or formation to be cut. Increasing the length of the upper moment arm can increase the force which can be generated against the work piece. However, this

requires a significantly larger tool body diameter, since the upper moment arm must have room to pivot within the tool body. Obviously, the tool body diameter is limited by the size of the borehole or tubular element through which the tool must be run.

Further, in such cutting and milling operations, the blades can become stuck in the deployed position, presenting great difficulty and expense in retrieving the tool from the borehole. This is because the piston or other force generator which applies force to deploy the blades is typically not capable of generating force in both the downward and upward directions.

It is desirable, then, to have a milling and cutting tool which can maximimize the blade force which can be generated against the workpiece, for a given tool body diameter. Further, it is desirable to have a milling and cutting tool which can generate force in both the downward and upward directions to both deploy and retract the pivotable blades.

BRIEF SUMMARY OF THE INVENTION

The present invention, in a preferred embodiment, has a plurality of pivotable blades mounted in longitudinal slots in a tool body. The blades pivot about pins near their upper ends. A piston below the blades, within the tool body, is slidably disposed to move upwardly against the lower ends of the pivotable blades. A passageway for drilling fluid is provided through the tool body and the piston, to a space within the tool body below the piston. Application of fluid pressure to this space below the piston exerts an upward hydraulic force, moving the piston upwardly against the blades. This upward motion of the piston exerts an upward and outward force against the lower ends of the blades, thereby exerting a maximized outward force on the blades, since the lower moment arm is a major portion of the full length of the blade. The piston and blade can have an angled slot-and-pin mechanism which exerts this upward and outward force. Alternatively, the piston can have a pin or roller which engages the lower edge and the inner edge of the blade at an angle. This latter structure can be particularly useful in the case where a long blade is to be fully extended from the tool body, such as for a multi-string casing cutter or an underreamer.

The piston can have a fluid inlet port through which the drilling fluid flows to reach the space below the piston. A ball or other closure member can be pumped downhole with the drilling fluid to close this fluid inlet port, resulting in the subsequent application of downward hydraulic pressure against the piston, driving it downwardly. Alternatively, a spring can be arranged between the piston and the body of the tool, to drive the piston downwardly upon release of hydraulic pressure. Downward driving of the piston can be used to retract the blades, particularly where the piston engages the blades by means of the slot-and-pin mechanism.

A fluid outlet port can be provided in the lower end of the tool body, below the piston. The piston can incorporate a plug which fits slidably into the fluid outlet port, to substantially block fluid flow through the outlet port, thereby maintaining a substantial hydraulic pressure against the lower end of the piston. The plug can be sized and configured so that it will withdraw from the outlet port when the piston has moved upwardly a sufficient distance to fully deploy the blades. This opening of the outlet port causes a significant drop in the fluid pressure below the piston, accompanied by a significant drop in the backpressure seen in the drilling fluid system. This acts as a positive indication to the operator that the blades are fully deployed. The angled slot or another angled surface on the piston can be configured to essentially lock the blades in the fully deployed position before the pressure drop is actuated. The plug can also have a series of undercuts at spaced intervals, to provide repetitive or progressive pressure drops, as the plug withdraws from the outlet port, which can signal the operator of the exact extent of piston movement, and consequently, the exact extent of deployment of the blades.

The novel features of this invention, as well as the invention itself, will be best understood from the attached drawings, taken along with the following description, in which similar reference characters refer to similar parts, and in which:

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

Figure 1 is a longitudinal section view of a section milling embodiment of the tool of the present invention, showing the piston in its lower position and the blade stowed;

Figure 2 is a longitudinal section view of the tool shown in Figure 1, showing the piston in its upper position and the blade deployed;

Figure 3 is a longitudinal section view of an underreaming or casing cutting embodiment of the tool of the present invention, showing the piston in its lower position and the blade stowed; and

Figure 4 is a longitudinal section view of the tool shown in Figure 3, showing the piston in its upper position and the blade deployed.

DETAILED DESCRIPTION OF THE INVENTION

A first embodiment of the apparatus of the present invention, as might be used for section milling, is shown in Figures 1 and 2. As shown schematically in Figure 1, the tool 10 of the present invention includes a hollow, substantially cylindrical, tool body 12, with a plurality of pivotable blades 14 and a slidable piston 20. The tool body 12 has a plurality of longitudinal slots in which the blades 14 are stowed. Each blade 14 is pivotably mounted to the tool body 12 near its upper end by means of a pivot pin 16. Each blade 14 comprises a knife body which has a removable and replaceable knife 18 mounted thereon, with a plurality of cutting elements dressed on the knives 18, by brazing or welding. The cutting elements can be crushed carbide particles, uniform carbide inserts, diamond inserts, or any other type of cutting element suitable for the intended use. A follower pin 36 is transversely mounted near the lower end of the blade 14.

A hollow, substantially cylindrical, hydraulic piston 20 is slidably mounted within the tool body 12, with the major width of the hollow piston 20 being directly below and substantially longitudinally aligned with the blades 14. The piston 20 has a plurality of outwardly extending lugs 29 which reside in the longitudinal slots in the tool body 12 in which the blades 14 are mounted. An angled slot 38 is formed in each of these outwardly extending lugs 29 of the piston 20, to engage the follower pin 36. A sleeve 31 extends upwardly from the top of the piston 20, to slidingly mate with the inner bore of the upper portion of the tool body 12. The piston 20 can obviously be constructed of several separate elements bolted together, for ease of assembly of the tool 10. It can be seen that the major width of the piston 20, essentially consisting of the outwardly extending lugs 29, is no greater than the approximate width of the blade

14, so that when the blade 14 is in its stowed position as shown, the overall diameter of the tool 10 is minimized, for a given piston area and for a given capability to generate hydraulic force. This allows the most powerful tool possible to be run into a borehole or tubular element of a given size.

A first fluid passageway 22 passes longitudinally through the tool body 12, and a second fluid passageway 24 passes longitudinally through the piston 20 and its sleeve 31. Drilling fluid, or another hydraulic fluid, can be pumped through the fluid passageways 22, 24 and into the space 26 within the lower end of the tool body 12, below the piston 20. This creates hydraulic pressure in the space 26, which generates an upward force on the lower end 28 of the piston 20, to drive the piston 20 in an upward direction. A plug 30 fixedly attached to the lower end of the piston 20 is positioned in a fluid outlet port 32 in the lower end of the tool body 12, below the piston 20. A plurality of ports 33 allow the drilling fluid to pass through the plug 30 and into the space 26. When the piston 20 is in its lowermost position, and during most of the upward travel of the piston 20, the plug 30 prevents any significant flow of drilling fluid out of the space 26, thereby maintaining the upward pressure on the piston 20.

As the piston 20 moves upwardly, as shown in Figure 2, the follower pin 36 near the lower end of the blade 14 follows the slot 38 in the lug 29 of the piston 20. As the pin 36 follows the slot 38, it is urged by an angled deflection surface 34 to move outwardly and upwardly relative to the tool body 12. As the follower pin 36 moves outwardly and upwardly, the blade 14 pivots outwardly and upwardly to engage the tubular element (not shown) which is to be cut. When the piston 20 approaches the upper end of its travel, the follower pin 36 moves into the outer, less angled, portion of the slot 38, essentially locking the blade 14 into its fully deployed position by outward pressure of the outermost portion of the angled deflection surface 34. Further, when the piston 20 approaches the upper end of its travel, the plug 30 withdraws from the fluid outlet port 32 in the lower end of the tool body 12. This significantly reduces the fluid pressure below the piston 20, thereby significantly reducing the drilling fluid backpressure which is monitored by the operator. This gives the operator a positive indication that the blade 14 is fully deployed.

A spring 27 is provided between the piston 20 and the tool body 12, to urge the piston 20 downwardly. Drilling fluid pressure can be released, allowing the spring 27 to move the piston 20 downwardly, thereby pulling the blades 14 inwardly by exerting a downward and inward force on the follower pin 36 with a second angled deflection surface 40 of the slot 38.

If the blade 14 becomes stuck in the deployed position, a closure device such as a ball 25, can be pumped downhole with the drilling fluid, and through the passageway 22 in the tool body 12 to block the passageway 24 in the piston 20. This allows the application of fluid pressure to move the piston 20 downwardly relative to the tool body 12. As the piston 20 moves downwardly, the follower pin 36 follows the slot 38, while the second angled deflection surface 40 urges the follower pin 36 to move inwardly and downwardly, thereby freeing the blade 14 and pivoting the blade 14 into its stowed position.

A second embodiment of the apparatus of the present invention, as might be used for multi-string casing cutting or formation underreaming, is shown in Figures 3 and 4. As shown in Figure 3, this embodiment of the tool 10 of the present invention includes a hollow, substantially cylindrical, tool body 12, with a plurality of pivotable blades 14 and a slidable piston 20. The tool body 12 has a plurality of longitudinal slots in which the blades 14 are stowed. Each blade 14 is pivotably mounted to the tool body 12 near its upper end by means of a pivot pin 16. Each blade 14 comprises a knife body which has a removable and replaceable knife 18 mounted thereon, with a plurality of cutting elements dressed on the knives 18, by brazing or welding. In this embodiment, the replaceable knife 18 is somewhat longer than the knife shown in the first embodiment, to make this embodiment more useful for multi-string cutting or formation underreaming.

A hollow, substantially cylindrical, hydraulic piston 20 is slidably mounted within the tool body 12, with the major width of the hollow piston 20 being directly below and substantially longitudinally aligned with the blades 14. The piston 20 has a plurality of outwardly extending lugs 29 which reside in the longitudinal slots in the tool body 12 in which the blades 14 are mounted. A deflection pin or roller 42 is transversely mounted on each of these outwardly extending lugs 29 of the piston 20, to engage the lower end of the blade 14. It can be seen that, here again, the major

width of the piston 20, essentially consisting of the outwardly extending lugs 29, is no greater than the approximate width of the blade 14, so that when the blade 14 is in its stowed position as shown, the overall diameter of the tool 10 is minimized, for a given piston area and for a given capability to generate hydraulic force. This allows the most powerful tool possible to be run into a borehole or tubular element of a given size.

A first fluid passageway 22 passes longitudinally through the tool body 12, and a second fluid passageway 24 passes longitudinally through the piston 20 and its sleeve 31. Drilling fluid, or another hydraulic fluid, can be pumped through the fluid passageways 22, 24 and into the space 26 within the lower end of the tool body 12, below the piston 20. This creates hydraulic pressure in the space 26, which generates an upward force on the lower end 28 of the piston 20, to drive the piston 20 in an upward direction. A plug 30 fixedly attached to the lower end of the piston 20 is positioned in a fluid outlet port 32 in the lower end of the tool body 12, below the piston 20. A plurality of ports 33 allow the drilling fluid to pass through the plug 30 and into the space 26. When the piston 20 is in its lowermost position, and during most of the upward travel of the piston 20, the plug 30 prevents any significant flow of drilling fluid out of the space 26, thereby maintaining the upward pressure on the piston 20.

As the piston 20 moves upwardly, as shown in Figure 4, the pin or roller 42 on the upper end of the piston 20 follows the lower and inside edges 44, 46 of the blade 14. As the pin or roller 42 follows the edges 44, 46 of the blade 14, the circumferentially angled deflection surface 34 of the pin or roller 42 exerts an outward and upward force on the blade 14, relative to the tool body 12. This causes the blade 14 to pivot outwardly and upwardly to engage the tubular element or formation (not shown) which is to be cut or underreamed. When the piston 20 approaches the upper end of its travel, the plug 30 withdraws from the fluid outlet port 32 in the lower end of the tool body 12. This significantly reduces the fluid pressure below the piston 20, thereby significantly reducing the drilling fluid backpressure which is monitored by the operator. This gives the operator a positive indication that the blade 14 is fully deployed.

Either embodiment of the tool 10 can also incorporate a series of undercuts 35 at regularly spaced intervals along the plug 30. As an alternative to undercuts, other forms of reduction of the cross sectional area of the plug 30 can also be used. The spacing between undercuts 35 can be, for example, one inch, or any other desired spacing. The undercuts 35 can be circumferential grooves in the outer diameter of the plug 30, as shown in Figures 3 and 4, or they can be progressively deeper undercuts in the outer diameter of the plug 30. In either case, when an undercut passes through the fluid outlet port 32, a corresponding drop in drilling fluid backpressure occurs. Where the grooved undercuts 35 are used, corresponding repetitive momentary pressure drops will occur. Where the progressively deeper undercuts 35 are used, corresponding progressive pressure drops will occur. Therefore, as the plug 30 withdraws from the fluid outlet port 32, repetitive or progressive drops in the drilling fluid backpressure can be observed by the operator. This gives the operator a positive indication of the exact position of the plug 30 and the piston 20 at any given time, which also gives the operator a positive indication of the extent to which the blades 14 are extended.

A spring 27 can be incorporated in the tool 10, positioned between an edge or shoulder of the tool body 12 and the piston 20, to urge the piston 20 downwardly. If the blade 14 becomes stuck in the deployed position, drilling fluid pressure can be lowered, and the downward bias of the spring 27 can move the piston 20 downwardly relative to the tool body 12. Either the spring 27 or the pumpable closure member 25 as described above can be used in either embodiment of the invention, or both features can be used, to move the piston 20 downwardly. Where the slot-and-pin mechanism is used to pivot the blades 14 as in the first embodiment, downward movement of the piston 20 can forcefully retract the blades 14. Where the pin or roller 42 is used to drive the blades 14 as in the second embodiment, downward movement of the piston can accomplish the forceful retraction of the blades 14 through the use of a properly placed additional pin or roller (not shown).

While the particular invention as herein shown and disclosed in detail is fully capable of obtaining the objects and providing the advantages hereinbefore stated, it is to be understood that this disclosure is merely illustrative of the presently preferred

embodiments of the invention and that no limitations are intended other than as described in the appended claims.

CLAIMS

We claim:

1. A well service tool, comprising:

a tool body, said tool body being attachable to a work string for lowering into a well bore;

a piston slidably mounted within said tool body;

a blade mounted on said tool body substantially above said piston, said blade being pivotably attached, about its upper end, to said tool body;

a blade deflection surface on said piston, said blade deflection surface being angled relative to the longitudinal axis of said tool body; and

a fluid passageway through said tool body to a space within said tool body below said piston, for application of fluid pressure to drive said piston upwardly within said tool body;

wherein said blade deflection surface is positioned to contact said blade upon upward motion of said piston, to force said blade to pivot outwardly about its upper end.

2. The well service tool recited in claim 1, wherein said blade is positioned substantially within a longitudinal slot in said tool body.

3. The well service tool recited in claim 1, further comprising:

an angled slot on said piston, said slot including said blade deflection surface; and

a follower pin on said blade, said slot engaging said follower pin to urge said blade to pivot outwardly and upwardly, as said piston moves upwardly.

4. The well service tool recited in claim 1, further comprising a pin on said piston, said pin including said blade deflection surface, said pin being positioned to engage said blade to urge said blade to pivot outwardly and upwardly, as said piston moves upwardly.

5. The well service tool recited in claim 1, wherein said blade comprises:

a knife body pivotably mounted to said tool body;

a replaceable knife removably mounted on said knife body; and

a plurality of cutting elements affixed to said replaceable knife.

6. The well service tool recited in claim 1, further comprising a second fluid passageway, through said piston, to a space within said tool body below said piston, said second fluid passageway being in fluid communication with said first fluid passageway through said tool body, for application of said fluid pressure to drive said piston upwardly within said tool body.

7. The well service tool recited in claim 6, wherein said second fluid passageway in said piston has an inlet port positioned for selective blockage by a closure device pumped downhole, enabling the application of fluid pressure to drive said piston downwardly.

8. The well service tool recited in claim 1, wherein:

said tool body is a substantially tubular body;

said piston is a substantially tubular body;

a wall of said piston has a major width no greater than the approximate width of said blade; and

said blade is substantially in longitudinal alignment with said piston wall.

9. The well service tool recited in claim 1, further comprising:

a fluid outlet port in said tool body below said piston; and

a plug attached to said piston, said plug being slidably disposed in said fluid outlet port to substantially close said fluid outlet port, said plug being configured to open said fluid outlet port when said piston has moved upwardly a sufficient distance to pivot said blade to a selected position, thereby substantially reducing fluid flow resistance through said tool body.

10. The well service tool recited in claim 1, further comprising:

a fluid outlet port in said tool body below said piston; and

a plug attached to said piston, said plug being slidably disposed in said fluid outlet port to substantially close said fluid outlet port, said plug being configured to at least partially open said fluid outlet port when said piston has moved upwardly a selected distance, thereby reducing fluid flow resistance through said tool body.

11. The well service tool recited in claim 10, wherein said plug has at least one undercut at a selected position on an outer surface of said plug, thereby partially opening said fluid outlet port to reduce fluid flow resistance through said tool body as said at least one undercut passes through said fluid outlet port.

12. The well service tool recited in claim 10, wherein said plug has a plurality of undercuts at selected positions on an outer surface of said plug, thereby partially opening said fluid outlet port at a plurality of positions of said plug, to repetitively reduce fluid flow resistance through said tool body as said plurality of undercuts pass through said fluid outlet port.

13. The well service tool recited in claim 10, wherein said plug has a plurality of undercuts at selected positions on an outer surface of said plug, thereby partially opening said fluid outlet port at a plurality of positions of said plug, to progressively reduce fluid flow resistance through said tool body as said plurality of undercuts pass through said fluid outlet port.

14. The well service tool recited in claim 1, further comprising a second blade deflection surface on said piston, said second blade deflection surface being angled relative to the longitudinal axis of said tool body, said second blade deflection surface being positioned to contact said blade upon downward motion of said piston, to force said blade to pivot inwardly about its upper end.

15. The well service tool recited in claim 1, further comprising a biasing means for urging said piston downwardly relative to said tool body.

16. The well service tool recited in claim 15, wherein said biasing means comprises a spring.

17. A well service tool, comprising:

a tool body, said tool body being attachable to a work string for lowering into a well bore;

a piston slidably mounted within said tool body;

a blade pivotably attached, about its end, to said tool body;

a fluid passageway through said tool body to a space within said tool body for application of fluid pressure to drive said piston longitudinally within said tool body;

a fluid outlet port in said tool body; and

a plug attached to said piston, said plug being slidably disposed in said fluid outlet port to substantially close said fluid outlet port, said plug being configured to at least partially open said fluid outlet port when said piston has moved a selected distance, thereby reducing fluid flow resistance through said tool body.

18. The well service tool recited in claim 17, wherein said plug is configured to open said fluid outlet port when said piston has moved a sufficient distance to pivot said blade to a selected position, thereby substantially reducing fluid flow resistance through said tool body.

19. The well service tool recited in claim 17, wherein said plug has at least one undercut at a selected position on an outer surface of said plug, thereby partially opening said fluid outlet port to reduce fluid flow resistance through said tool body as said at least one undercut passes through said fluid outlet port.

20. The well service tool recited in claim 17, wherein said plug has a plurality of undercuts at selected positions on an outer surface of said plug, thereby partially opening said fluid outlet port at a plurality of positions of said plug, to repetitively reduce fluid flow resistance through said tool body as said plurality of undercuts pass through said fluid outlet port.

The Patent Office

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Application No: GB 0018327.7
Claims searched: 1-16

Examiner: R L Williams
Date of search: 29 November 2000

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): E1F (FCJ)(FLA)

Int Cl (Ed.7): E21B 10/32,29/00

Other: EPODOC,WPI,JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB 2,316,965 A	Baker Hughes Incorporated	1,2,5,6,8,15,16
X	US 5,350,015	C D Hailey	1,2,5,6,8,15,16
X	US 5,018,580	U Skipper	1,2,5,6,8,15,16

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.